Integrated Process Risk Management (IPRM) for Refineries and Petrochemical Complexes

K. Torabi, B. Karimi, R. Parmar, M. Oliverio and K. Dinnie

Nuclear Safety Solutions Ltd. Toronto, Ontario, Canada
Why IPRM is needed?
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- The operation of refineries, petrochemical complexes and nuclear power plants is so complicated that, in many situations, engineering, maintenance and operating decisions cannot be easily prioritized nor optimized solely on an individual’s knowledge and experience.
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- The operation of refineries, petrochemical complexes and nuclear power plants is so complicated that, in many situations, engineering, maintenance and operating decisions cannot be easily prioritized nor optimized solely on an individual’s knowledge and experience.

- This is where IPRM tools can play a very important role to integrate the human knowledge & experience with actual statistical data & mathematical models in order to simplify, prioritize and optimize the decision making process.
Objective
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- The objective of this presentation is to show how the IPRM can be used to quantify and optimize the maintenance activities in refineries, petrochemical complexes, power plants, and any other large-scale manufacturing plant.
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- Who would be interested in the IPRM toolbox?
  - Plant managers
  - Insurance companies
  - Investors
  - Environmental and Safety Regulators or Commissioners
IPRM Outputs
Daily engineering and plant management duties include tasks to:
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- Quantify risks associated with equipment failures in different processes. **Determine the significance** of the failures in terms of production losses ($).
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- **Prioritize maintenance** activities, and plant modifications in different processes and units for different equipment.
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- Quantify risks associated with equipment failures in different processes. **Determine the significance** of the failures in term of production losses ($).
- **Prioritize maintenance** activities, and plant modifications in different processes and units for different equipment.
- **Optimize the frequency** of inspections and equipment testing.
How is IPRM model developed?
Plant Design Documents and Drawings
(PFDs and P&IDs)
+
Operational and Maintenance Data
(Process Engineers & Maintenance Staff
Historical Data, Work Orders, Human Errors
Failure Events, Event Durations & Frequencies)
IPRM steps
1. Identifying major components for each process in which their failures lead to production loss (e.g., pumps, valves, heat-exchangers, generator). Operating history helps to identify key components and events in each process.
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2. Defining the failure modes for the important components (including Human Errors).
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2. Defining the failure modes for the important components (including Human Errors).

3. Classifying failures into certain production loss categories (e.g., 10%, 50% or 100% production losses). These inputs are obtained from process engineers and operators.
IPRM steps
4. Assigning failure rates to each failure mode, using either the generic data bases or plant specific data.
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5. Assigning recovery times to each failure event (i.e., plant experience).
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5. Assigning recovery times to each failure event (i.e., plant experience).

6. and finally, summarizing everything in a table, so that a fault-tree model can be produced.
Modeling Procedure: Start with the PFD of each process unit.
Modeling Procedure: From PFD to more detailed drawings (e.g., P&ID)
Modeling Procedure: From P&ID to Fault-Tree Diagram (Boolean algebra)
## Modeling Procedure: From Fault-Tree Diagram to MS Excel Spreadsheet

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Some of the main processes in a typical refinery are:

- Fractionation (atmospheric & vacuum distillation)
- Fluidized Catalytic Cracking
- Hydrocracking
- Alkylation
- Isomerization
- Reforming
- Extraction
- Dewaxing
- MTBE unit
IPRM Output

Process Significance Ranking

- VACUUM
- COOLING WATER
- I&C
- ISOMERIZATION
- ALKYLATION
- ISOMAX
- FCC
- ELECTRICAL
- LUBE TOWER
- STEAM
- FRACTIONATION
Maintenance Optimization

in

Cooling Water Supply System of a 50,000 BPD Refinery
Problem Definition

With $50K budget, and known history of problems in Cooling Water system:
Where should the money be spent to maximize the reliability of the cooling water supply system?
Cooling Water Supply System in a Refinery

Heat & Material Balance

ATMOSPHERIC

DISTILLATE

REFORMER

CRACKING

ALKYLATION

VACUUM LUBE TOWER
Cooling Water Supply System in a Refinery

Heat & Material Balance
Cooling Water Supply System in a Refinery

Heat & Material Balance
Cooling Water Supply System in a Refinery

Heat & Material Balance
Cooling Water Supply System in a Refinery
Cooling Water Supply System in each process unit
Cooling Water Supply System in each process unit
Maintenance Optimization and Design Prioritization
Adding a new standby cooling water supply pump for summer heat peaks?

OR

Adding a valve for cooling water supply to the fractionation main condenser?
Adding a new standby cooling water supply pump for summer heat peaks?  

OR

Adding a valve for cooling water supply to the fractionation main condenser?
Supply CW Pump Arrangement
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Adding a 4th pump to the existing 3 parallel pumps in the CW loop?
Adding a 4th pump to the existing 3 parallel pumps in the CW loop?

- Existing CW loop has 3 pumps. Depending on cooling loads at different time of year, 1, 2 or all 3 pumps are running.
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- In **hot summer days** (P=0.2), when all 3 pumps are running there is no standby pump available.
- Trip of one (1/3) of the pumps in hot summer days, would require one or two of the processes to be shutdown (i.e., 40% loss in total production).
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- Trip of **one** \( (1/3) \) of the pumps in hot summer days, would require one or two of the processes to be shutdown \( \text{(i.e., 40\% loss in total production)} \).  
- Trip of **two** \( (2/3) \) of the pumps in summer, forces the plant to be shutdown \( \text{(i.e., 100\% loss)} \).
Cooling Water Supply System

100% Loss

40% Loss

10% Loss

Enhancing performance through partnering
Adding a 4th pump to the existing 3 parallel pumps in the CW loop?
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- Build the IPRM model with 4 pumps and compare the result with the same model with 3 pumps.
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- Compare the total annual losses for each design; before and after the modification:
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**REDUCED RISK**

- 350,000 lit/yr (with 3 pumps) - 348,000 lit/yr (with 4 pumps) x $0.1/lit (net-profit) = $200 profit loss prevented/yr
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**MODIFICATION COSTS**: $50,000 investment.
Adding a 4th pump to the existing 3 parallel pumps in the CW loop?

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  348,000 lit/yr (with 4 pumps) x $0.1/lit (net-profit) =
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  **MODIFICATION COSTS** > $50,000 investment.

- 250yrs ROI; Obviously not a high priority proposal!
Adding a 4th pump to the existing 3 parallel pumps in the CW loop?
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The numbers were based on a plant located in Ontario, Canada. However, if the plant was located in Texas or somewhere in Saudi Arabia, the decision could be different!
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- **The probability of hot summer days would be different** ($P > 0.2$)
- **The plant operating experience (i.e., historical failure rate) of the pumps could be different.**

As a result, the conclusion could be different.
Maintenance Optimization and Design Prioritization

Adding a new standby cooling water supply pump for summer heat peaks?

OR

Adding a valve for cooling water supply to the fractionation main condenser?
CW supply control valve

Fractionation
Heatexchanger
CW supply control valve

Fractionation
Heatexchanger
Adding a 2\textsuperscript{nd} valve parallel to the existing CW supply valve (PV501)

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Adding a 2\textsuperscript{nd} valve parallel to the existing CW supply valve (PV501)

The most important sequences of events?

<table>
<thead>
<tr>
<th>Frequency (occr/yr)</th>
<th>Event1</th>
<th>Event2</th>
<th>Event3</th>
<th>Durations (hrs)</th>
<th>Production Loss Ratio</th>
<th>Unit Capacity (liter/hrs)</th>
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2yrs ROI; Implement this modification as soon as possible √
Summary

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Thank You
PM frequency optimization
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- Additional preventive maintenance, upgrading pumps, or gland-seals would reduce the failure frequency from 0.01 trips/yr to 0.001 trips/yr
- Additional preventive maintenance would cost $3,000/yr
- The new ROI would be 25yrs. Still you may decide against the additional maintenance, and allocate the existing resources to other equipment.